Development of a nuclear reaction database on silicon for simulation of neutron-induced single-event upsets in microelectronics and its application

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The radiation effects known as single-event upsets(SEUs) in microelectronics have recently been recognized as a key reliability concern for current and future silicon-based integrated circuit technologies. Cosmic-ray neutrons having a wide energy range from MeV to GeV are regarded as one of the major sources of the SEUs in the devices used on the ground or in airplanes. Therefore, nuclear reaction data to describe the interaction of neutrons with the nuclides contained in the devices are highly requested as a fundamental physical quantity necessary for understanding the SEU phenomena and estimating the SEU rate. To meet this demand, we have recently developed a cross section database for silicon, using evaluated nuclear data file (JENDL-3.3, JENDL-HE, and LA150) and QMD calculation, for neutron energies ranging from 2 MeV to 3 GeV. Using the cross section database and the energy loss calculation of secondary ions, one can simulate the initial SEU processes, namely generation of secondary ions via nuclear reactions and initial charge distribution induced in the device. In the present work, a simple device structure with only silicon layers is taken into account, and the SEU cross sections are calculated on the basis of the initial processes simulated in terms of a Monte Carlo method. Two major parameters, the sensitive volume and the critical charge of the device, are included in the calculation. We have analyzed the experimental data for SRAMs and the other simulation result for DRAMs using this model calculation. It is shown that the dependence of SEU cross sections on incident neutron energy is reproduced satisfactorily by adjusting the two parameters. Through these analyses, we investigate the secondary ions generated by nuclear reactions with Si and the incident energy range which have the most important impact on SEUs. The sensitivity of the nuclear reaction data on SEUs is also discussed.

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